Measuring the Fire-Induced Velocity Flux in a Doorway with Particle Image Velocimetry

Rodney A. Bryant
NIST
Building and Fire Research Laboratory
Fire Metrology Group

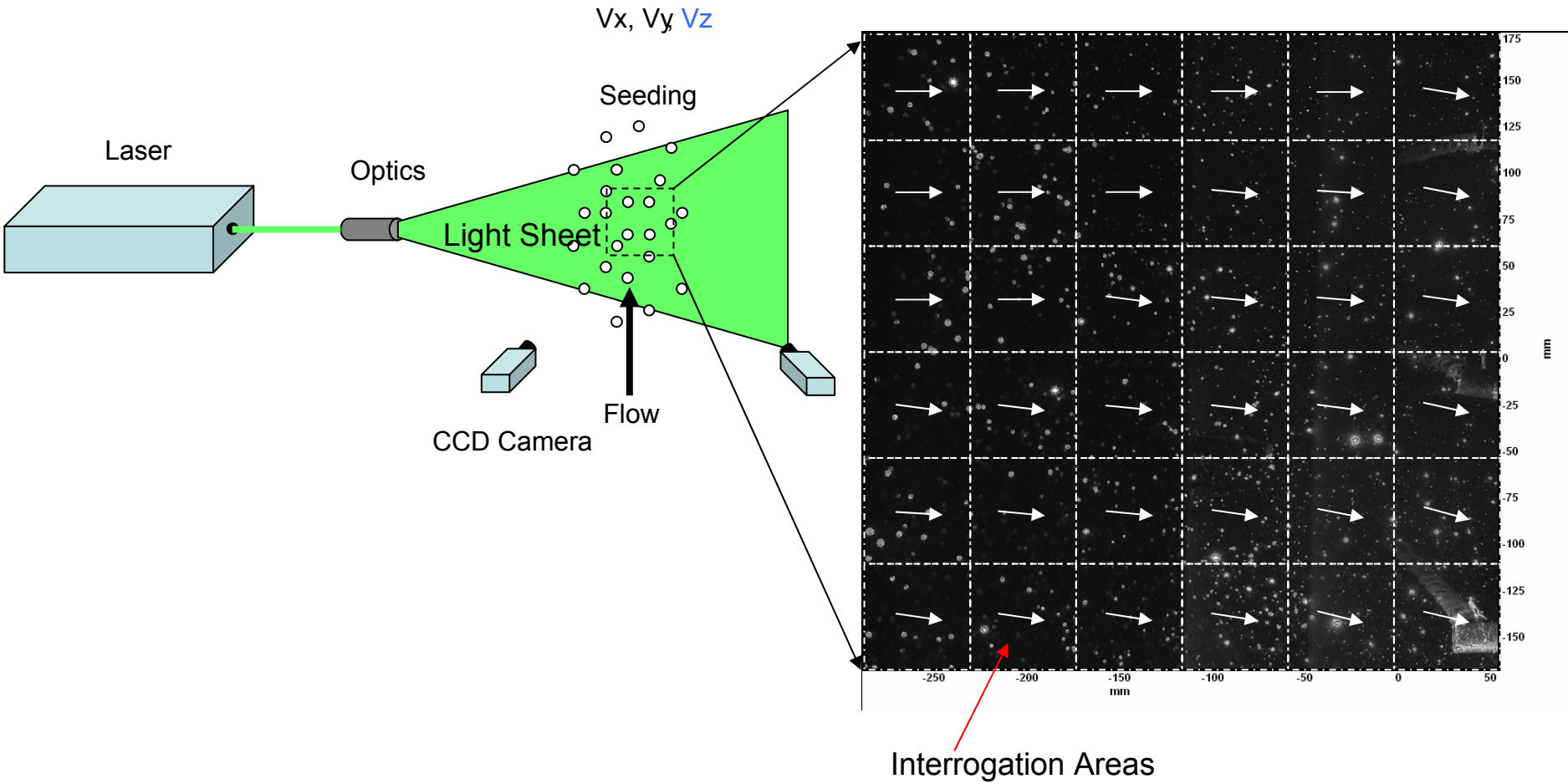
Background

- Objective
  - To improve gas velocity measurements in full-scale fire-induced flows by implementing state-of-the-art measurement techniques (Particle Image Velocimetry - PIV)
- Outcome
  - Better physical evidence to support and improve our interpretations of the physical processes of enclosure fires
  - Better data for confirmation of conventional measurement and modeling techniques
- Historical Perspective
  - K. Steckler, H. Baum, J. Quintiere, Fire Induced Flows Through Room Openings – Flow Coefficients, Proceedings of the Combustion Institute, 20 1591-1600 (1984)

Instrument	Measured Quantity	Local Inferred Quantity	Global Quantity
Thermocouples	T	$\rho(y) \sim {}^{1}\!/\!_{T(y)},$ $V(y) \sim \Delta\rho(y)$	$\dot{V} \sim W\int V(y)\partial y$ $\dot{m} \sim W\int \rho(y)V(y)\partial y$
Diff Press Xdcrs (bdp)	ΔP	$V(y) \sim \sqrt{T(y)\Delta P(y)}$	
Stereo PIV	Δd	$V_x(x,y) \sim \Delta d_x(x,y)$ $V_y(x,y) \sim \Delta d_y(x,y)$ $V_z(x,y) \sim \Delta d_z(x,y)$	$\dot{V} = \iint V_z(x,y)\partial y\partial x$ $\dot{m} \approx \iint \rho(y)V_z(x,y)\partial y\partial x$

Review of PIV

V = displacement / time



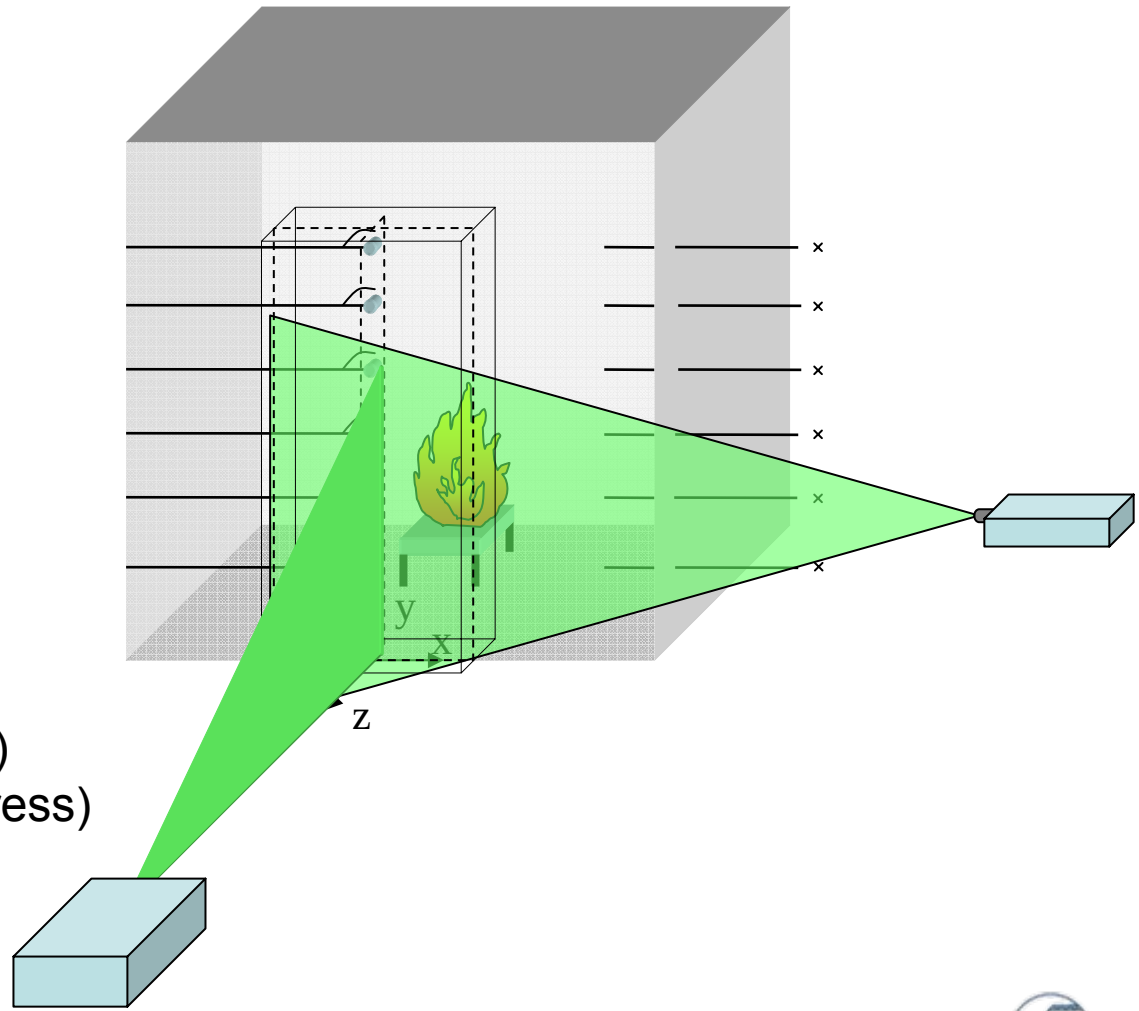
Experiment Overview

Enclosure Fire
- single vent (doorway)
- outflow
- inflow

ISO 9705 Room
- interior dimensions
  (3.6 x 2.4 x 2.4) m
- doorway dimensions
  (0.79 x 1.96) m

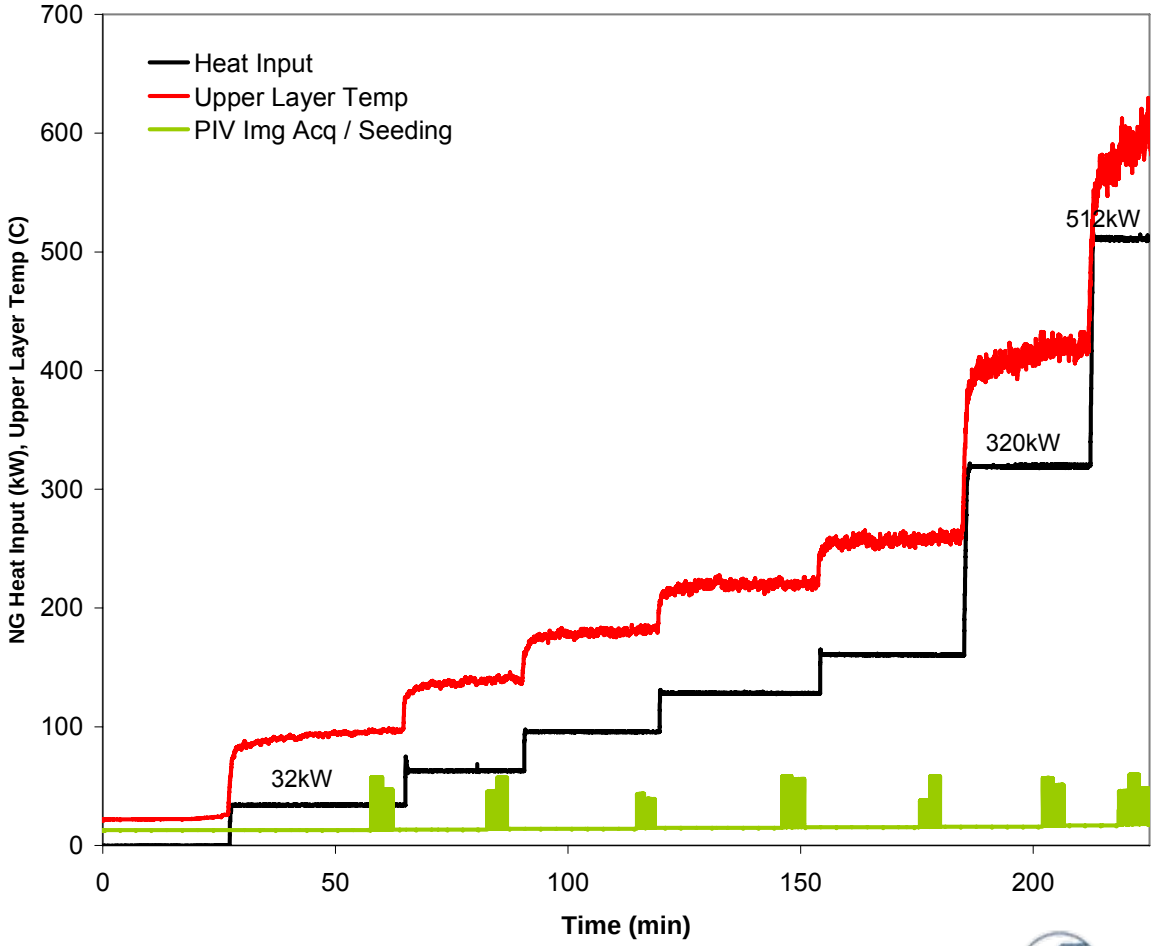
Well controlled heat source
- natural gas burner
- over ventilated fires

Instrumentation
- thermocouple arrays (temp)
- bi-directional probes (diff press)
- Stereo PIV (in flow only)

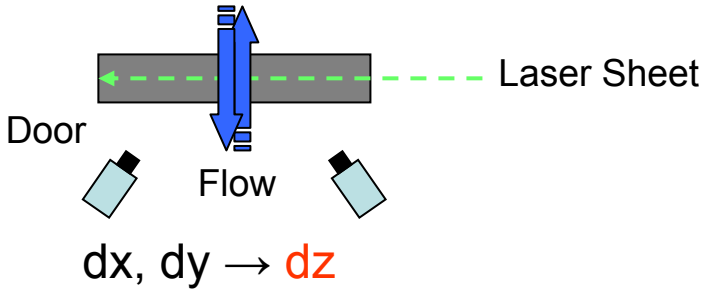


Experiment Process

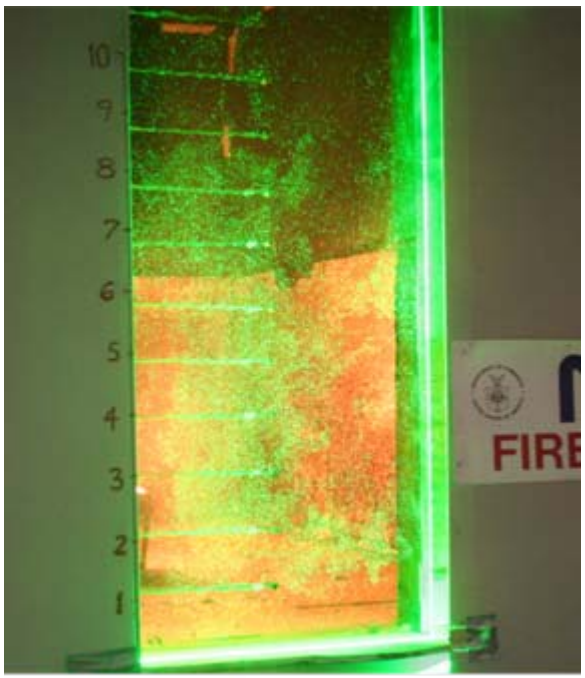
Parameter	No. Exp
Total Exp	10
Doorway Velocity (PIV)	9
Room Temperature (Asp TC)	5
Doorway Temperature and Differential Press (BDP)	4
Heat Release Rate (O_2 Calorimetry)	3
Max Fire, 512 kW	5

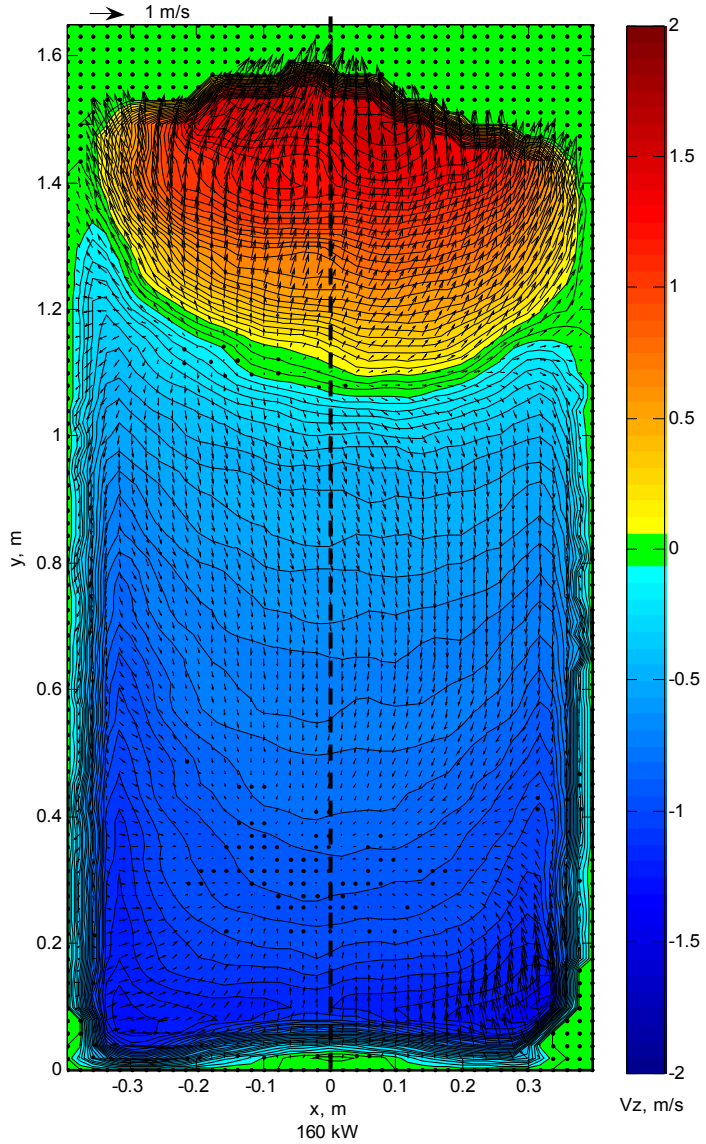


PIV Flux Slice, z=5cm

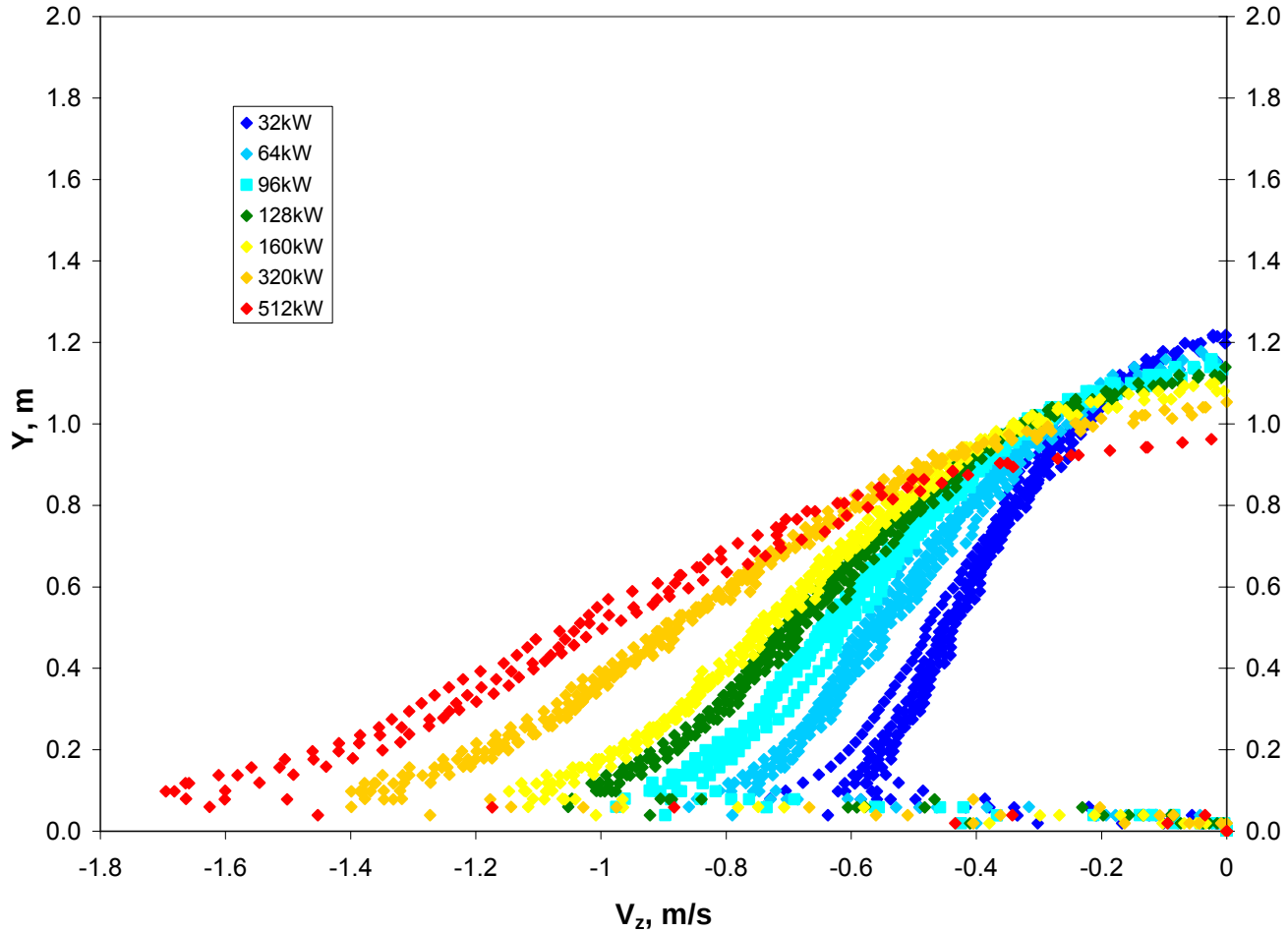


dx, dy → dz

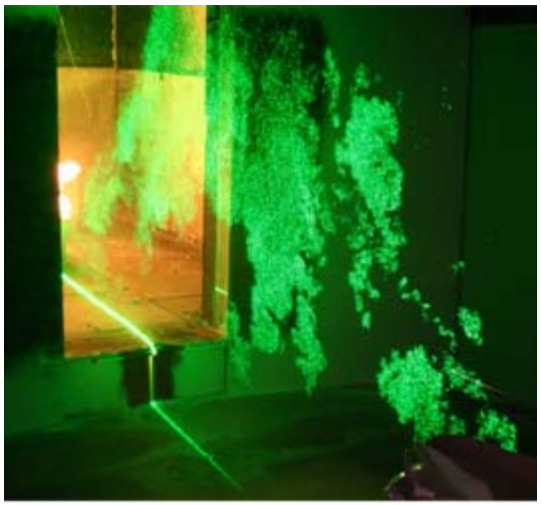


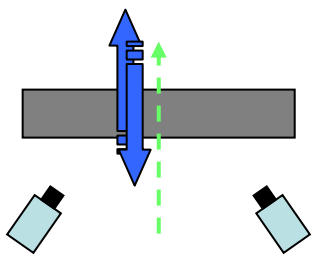


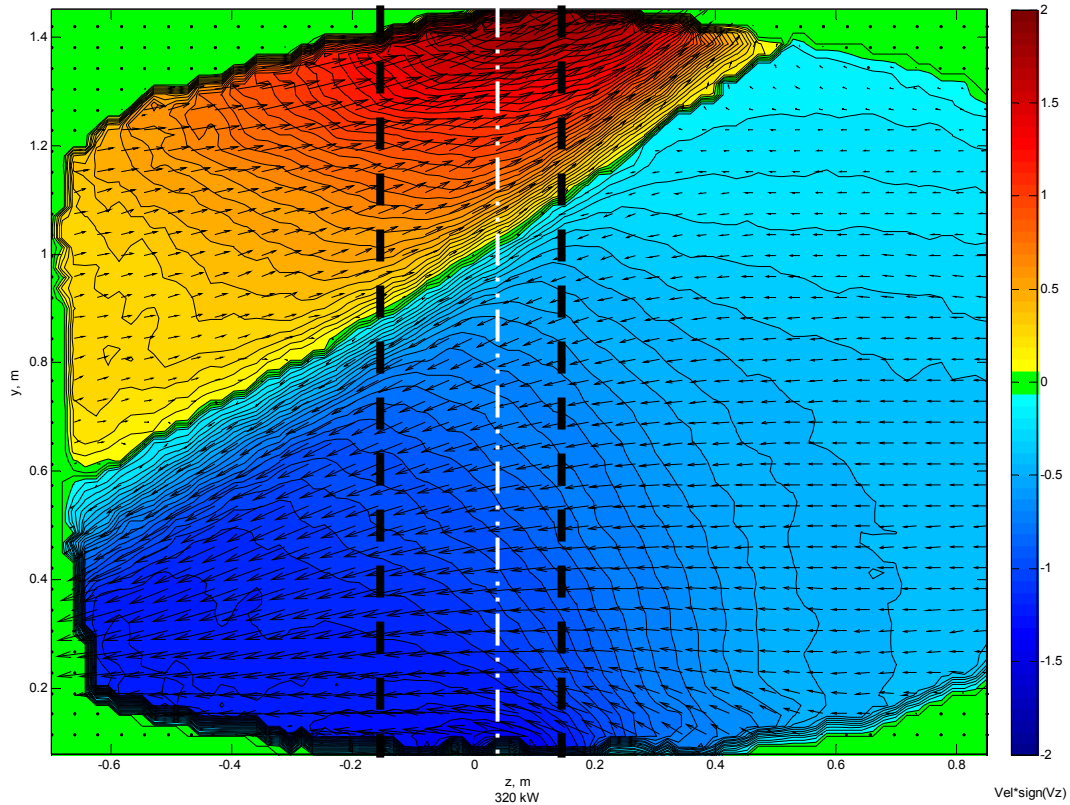
Vertical Profiles from Flux Slice; x=0cm, z=5cm



PIV Centerline Slice, x=0cm

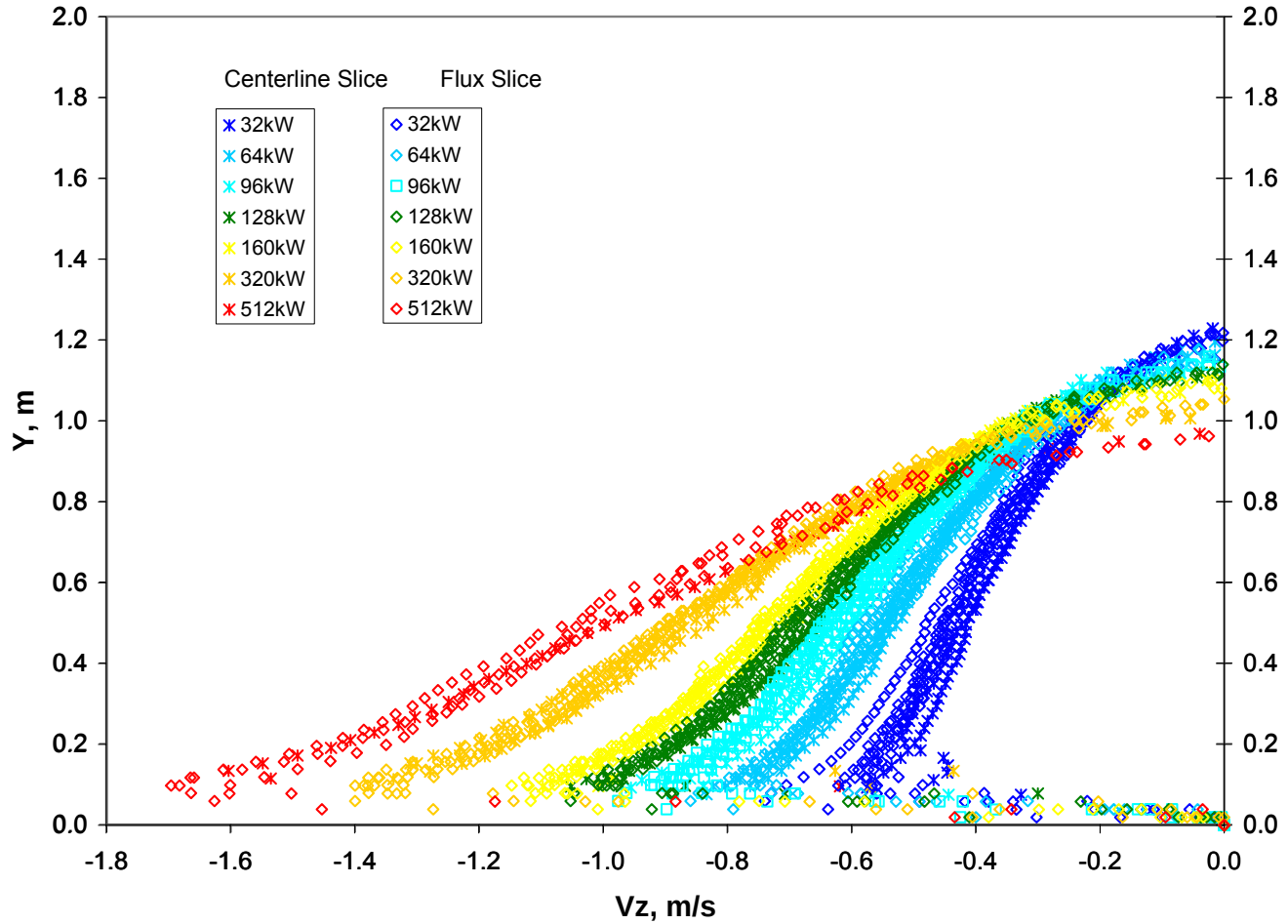




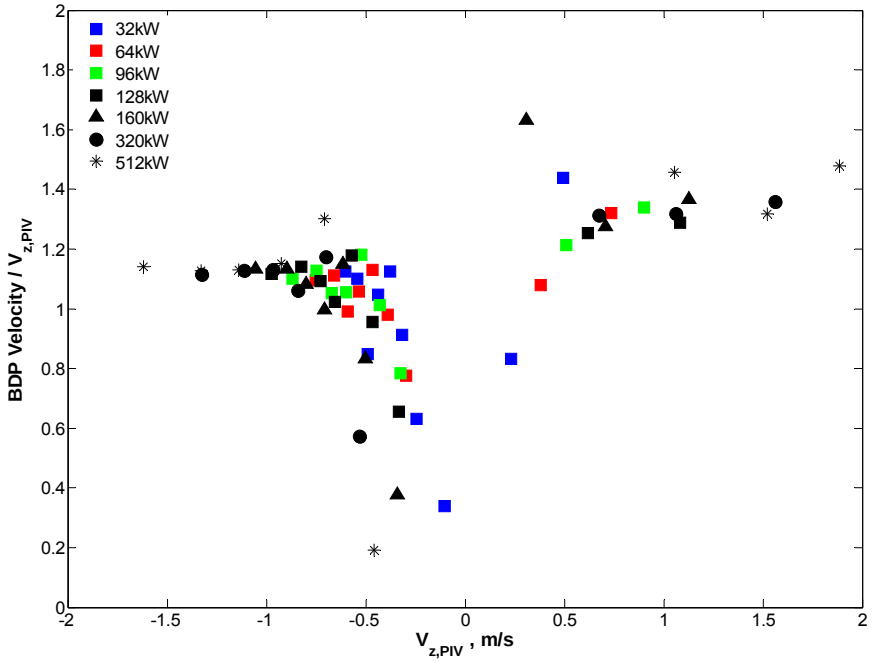


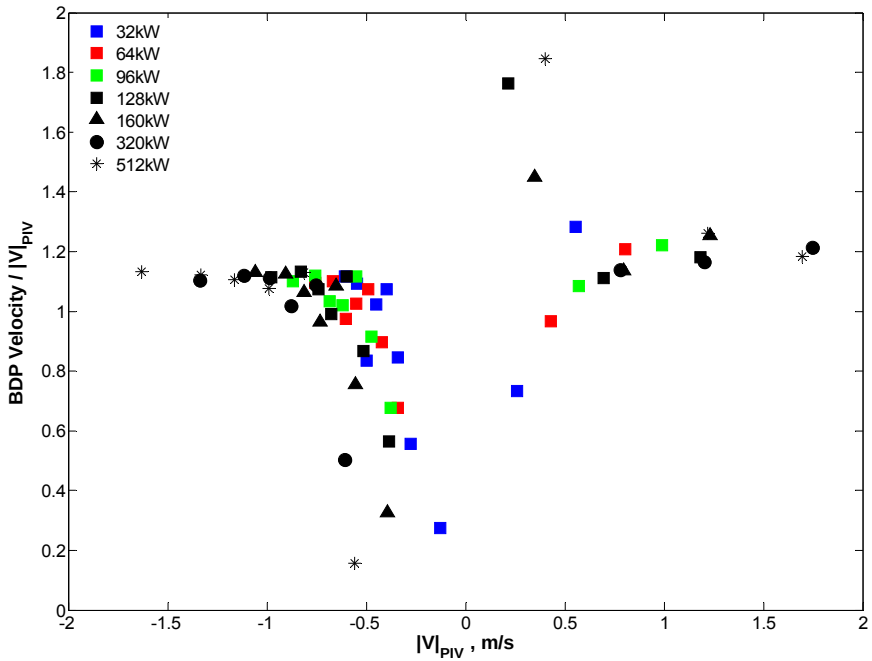
Interior Door Jamb Exterior

Vertical Profiles from Centerline Slice, x=0cm, z=5cm

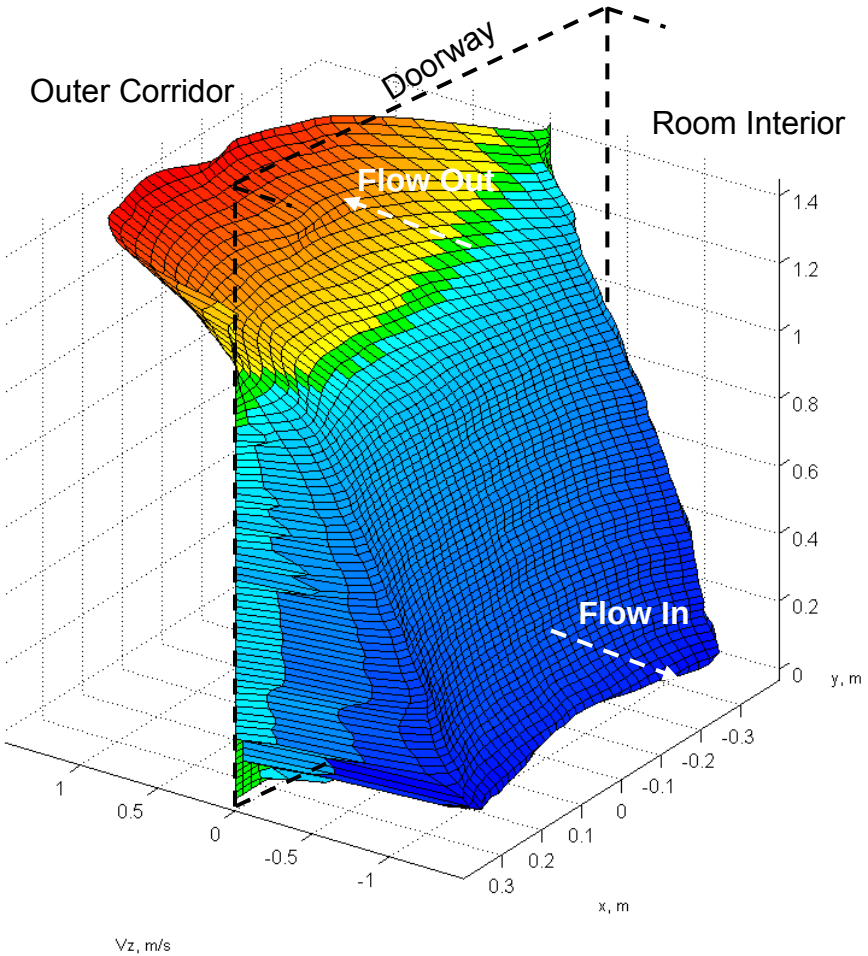


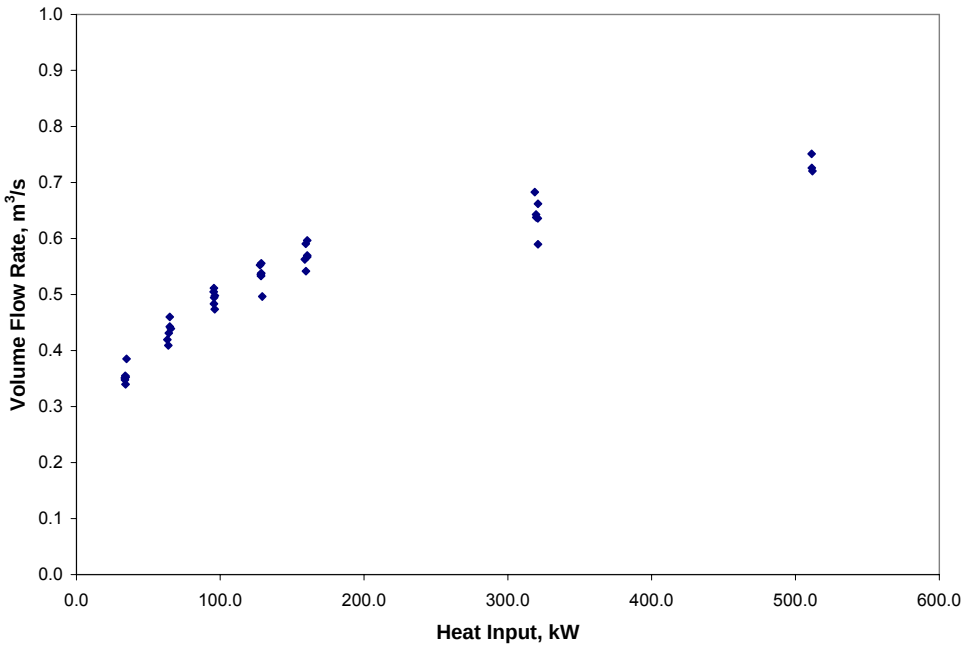
Comparison of PIV and BDP Results - 2





Velocity Flux of Air Into the Room





Summary

- Stereo PIV has been applied to a full-scale fire-induced doorway flow
  - the flow into the room was fully mapped
  - the complete velocity vector was measured, (V_x, V_y, V_z)
  - volume flow rate or velocity flux was computed

- Confidence in the PIV results is supported by
  - good repeatability between experiments
  - good agreement between the PIV methods

- The conventional flow measurement technique, the bi-directional probe, has been challenged by an independent technique
  - discrepancy is not unreasonable but there is room for improvement
  - PIV provides a tool for better interpretation of the response of the bi-directional probe